

Paper ID: 374

**Theme: 1.** Grassland Resources**Sub-Theme: 1.2.** Global monitoring of grasslands

## The value of modeling botanical composition change in grasslands

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### Introduction

The integration of grassland dynamics, livestock production and economics is necessary to improve decision making regarding grassland resource development and management. Within a sward, the relative competitive ability of different species and the way management interacts with the environment both play a significant role in determining the competition between species, future states of the grassland sward, ecological impact of the grassland and its potential for livestock production (Kemp and King, 2001). The impact of botanical composition shifts on grassland productivity will depend on the nutritive value and yield potential of the invasive species against those of the resident species. The seasonality and spatial distribution of forage and its quality will influence selective grazing, livestock productivity and potential profitability from the grassland.

Long-term grazing trials in Australia have described how the persistence of different species interacts with management and climate to determine the resilience of a pasture system. Most large changes in grassland populations are episodic and coincide with either favourable growing conditions or periods of stress, especially under conditions of overgrazing and drought. Annual cycles in botanical composition are a continually dynamic seasonal process that over the long term may reflect the dominance of a particular functional group of species (Kemp and King, 2001). It has been suggested that the state and transition model proposed by Westoby *et al.* (1989), adequately represents Australian grasslands.

The modelling of functional groups, in terms of their seasonality of growth, responses to drought and grazing, capacity for livestock production and environmental value, would enhance the applicability of the state and transition model to grassland resource and management decision making systems in broadly different environments. This is supported by previous work where ordination of grassland survey data showed similar group interactions and relative changes define the variable states of grasslands and transitions between states in response to both management and climate (Westoby *et al.*, 1989; Kemp and King, 2001). Modelling functional groups also allows incorporation of desirable native or naturalized species that fit into sown species functional groups, as some native species in Australian grasslands make significant contributions to grassland productivity, sustainability and profitability.

The objective of this study is to determine the value of modelling botanical composition changes in grasslands under both stochastic and deterministic climatic conditions. This value is measured through its simulated effects on both biophysical and economic outcomes.

### Materials and Methods

The method applied within the Dynamic Pasture Resource Development (DPRD) model, used in this study and detailed in Behrendt *et al.* (2013), adapts the method proposed by Loewer (1998) on the use of partial paddocks and the concepts of state and transition models. In the DPRD model the spaces occupied by two functional groups, desirable and undesirable, are assumed to be variable and respond to climate, management (including selective grazing) and inputs. This enables the cycles of grassland degradation and restoration (including re-sowing of desirable species) to be adequately modelled. This empirical modelling approach separates the yield from the basal area of different species groups to provide a more meaningful and stable indicator of ecological or botanical composition change. The model simulates an infinite number of stable states from which either negative or positive transitions may occur over time.

The area occupied by the desirable group is modelled as an exploitable renewable resource using differential equations that describe population growth and harvesting impact (Clark, 1990). Population growth in the absence of grazing is defined through a logistic growth model, concurrently the impact of harvesting livestock relates to desirable utilization. This implicitly assumes that undesirable species are invasive and opportunistic when the area of desirables declines. It also assumes that desirables will expand their basal cover and move towards attaining sward dominance if given the opportunity through adequate soil fertility, tactical grazing rests or reduced grazing pressure during favourable seasons.

Each functional group has different growth potentials, seasonal patterns, responses to changes in soil fertility, and dry matter digestibilities. These factors combine to influence the stochastic nature of feed availability and livestock

production. Data from individual species measured in the Cicerone farmlet experiment were classified and clustered into species type and growth pattern to identify representative species for modelling in the more complex *AusFarm* model to calibrate and derive parameters for the DPRD model (Behrendt *et al.*, 2013).

Simulation experiments tested the effects of a range of stocking rates and fertilizer input rates on wool and sheep meat production and profitability (Behrendt *et al.*, 2013). To determine the value of accounting for botanical composition changes over time, combinations of both static and dynamic models of grassland composition were tested in conjunction with deterministic and stochastic climatic conditions. Under static and deterministic conditions botanical composition remained at its initial value (44% desirable: 56% undesirable) and climate represented an average year. Under dynamic and stochastic conditions each simulation experiment ran over a period of 10 years with 300 iterations of randomized annual climate datasets drawn from a 30-year period (1976-2006). Ten stocking rate levels (3-30hd/ha set-stocked) were tested under a moderate level of fertilizer application.

## Results and Discussion

Stochastic simulations revealed large changes and variability in the state of grassland resources, livestock production and economic returns across tested stocking rates (Behrendt *et al.*, 2013). The difference between the maximum deterministic gross margin (GM) and the maximum stochastic GM indicate the expected cost of accounting for stochastic climatic conditions and dynamic botanical composition. In the simulated grassland, this expected cost represents a 16.4% reduction overall in maximum GM (\$56AUD/ha difference).

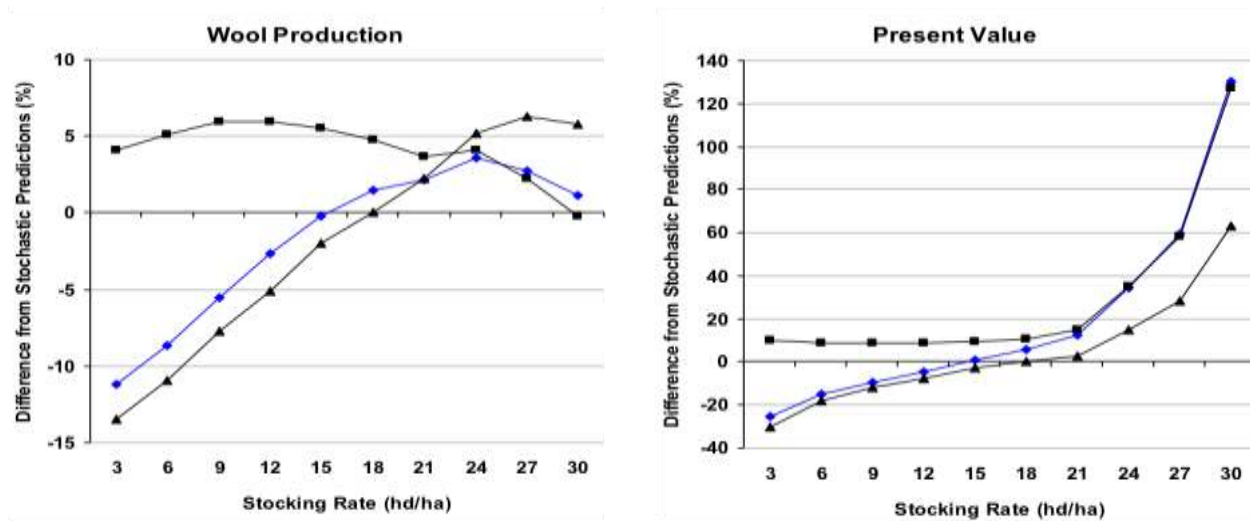
Table 1 presents the mean percentage differences between the stochastic/dynamic base case predictions and different combinations of climate conditions and botanical composition modelling across all stocking rates (calculated as deterministic/static combinations less stochastic/dynamic predictions). Results indicate that a deterministic climate, on average, had the largest effect on overestimating production and returns. Static botanical composition models overestimated production and profitability, but at a lower level to that of climate. Live weight change was influenced most by a deterministic climate and static botanical composition, with wool production being less sensitive.

The relationship between stocking rate and varying combinations of climate condition and composition modelling, when compared against stochastic/dynamic predictions of wool growth and present value (Figure 1) indicate that, at stocking rates of less than 15 head/hectare, static botanical composition increasingly caused the underestimation of wool production and present value. With higher stocking rates, wool production and present value were overestimated under a deterministic climate and static botanical composition.

The underestimation of production and profit at low stocking rates was the result of no improvement in the grassland's botanical composition over time. Increases in the desirable proportion would have increased pasture growth during autumn, winter and spring, and improved feed quality on offer. Under high stocking rates the desirable proportion is maintained and thus growth rates and feed quality are overestimated. The effect of these changes on grassland production and quality are expressed by the differences observed between stochastic and deterministic livestock production. The results also suggest that the undesirable proportion of the sward plays a significant role in determining the productivity and profitability of the grazing system.

**Table 1:** Mean percentage differences in performance measures between the stochastic/dynamic base case and different combinations of deterministic climatic and static botanical composition conditions.

Performance Measure	Deterministic climate & static botanical composition	Deterministic climate & dynamic botanical composition	Stochastic climate & static botanical composition
Wool (annual average)	0.0	3.7	0.5
Fibre diameter (annual average)	-1.1	1.0	-1.0
Liveweight (annual average)	75.3	135.3	35.8
Gross Margin (annual average)	20.1	28.0	6.2
Present Value (10 years)	18.1	25.8	4.8



**Fig. 1:** Percentage difference from stochastic/dynamic simulation output for wool production and Present Value under different stocking rates when compared against deterministic climate/static botanical composition (◆); stochastic climate/static botanical composition (▲); and deterministic climate/dynamic botanical composition (■).

## Conclusion

The cost of ignoring climate variability and the dynamics of the grassland resource has been shown to be large under certain conditions. Over- or under-estimations of production and profit would lead to sub-optimal decision making on the development and management of a grassland resource. This is supported by others who have demonstrated the importance of species persistence on the economics of sown pastures and the role of tactical grazing rests to promote the persistence of desirable species (Behrendt *et al.*, 2013). The dynamic botanical composition model was shown to be less important than a stochastic climate in predicting the production and profit from a system. These comparisons indicate that accounting for the dynamic nature of grassland resources and the impact of climate risk is important in the identification of optimal pasture development and management decisions. Hence it is also of great importance to note changes in grassland resource condition when reporting and analyzing the outcomes of field experiments.

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